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# Implications for Early Postoperative Care After Quadriceps Tendon Autograft for Anterior Cruciate Ligament Reconstruction: A Technical Note

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The quadriceps tendon (QT) has become increasingly used by orthopaedic surgeons as an alternative autograft choice in anterior cruciate ligament reconstruction. As its use increases, athletic trainers and other rehabilitation clinicians will treat a greater number of patients with this autograft type. The recently developed, minimally invasive technique for harvest of the all-soft tissue autograft has many benefits, including versatility, decreased donor-site morbidity, and enhanced cosmesis. Early clinical trials revealed that the QT autograft resulted in decreased anterior knee pain and similar strength and functional outcomes to those of more common autograft types. From a rehabilitation perspective, many characteristics should be considered, such as the importance of early knee extension and quadriceps activation. Therefore, the purpose of this technical note is to expose athletic trainers to the QT autograft so that they may provide the best care for patients after anterior cruciate ligament reconstruction.

***Key Words:*** knee, rehabilitation, therapy

The concept of individualized anterior cruciate ligament reconstruction (ACLR) is used by many orthopaedic surgeons when choosing patient-specific reconstructive procedures, including autograft type.[1] Graft choice is based on patient characteristics and goals. A number of different autograft options exist, with bone–patellar tendon–bone (BPTB) autografts being the standard autograft of choice in the United States.[2] However, these grafts are associated with complications, such as patellar fracture, patellofemoral pain, increased donor-site morbidity, arthrofibrosis, and quadriceps weakness after surgery.[3,4] Additionally, the BPTB autograft predisposes patients to a greater risk of knee osteoarthritis than other autograft types.[3,5] Quadrupled-hamstrings (QHS) autografts have been used with success as an alternative to BPTB autografts. However, QHS autografts have shown higher rates of failure than BPTB autografts,[6–8] and undersized grafts can be problematic in small-statured patients.[9] These concerns prompted the search for a more viable autograft.

The quadriceps tendon (QT) autograft for ACLR was first described by Marshall et al[10] in 1979. In 2010, the QT autograft represented only 2.5% of all autografts used in ACLR.[11] Since then, clinical use of the QT autograft has been steadily increasing. Research publications regarding the QT autograft have doubled in the past 10 years. This was due to significant surgical advances, particularly fixation techniques that resulted in an efficient and reliable harvesting technique for the all–soft tissue QT autograft.[12] Additionally, the QT provides favorable anatomy and biomechanics, low donor-site morbidity, and positive clinical outcomes for many patients. Despite these outcomes, the clinical practice guidelines from the American Academy of Orthopaedic Surgeons,[13] which are endorsed by the National Athletic Trainers' Association, excluded all studies that involved QT autografts. To date, the *Journal of Athletic Training* has not published any studies on QT autografts. As more orthopaedic surgeons are trained to use this autograft type, athletic trainers and other rehabilitation clinicians will need to be well versed in the current evidence. Thus, the purpose of this technical note is to describe the orthopaedic procedure and implications for early postoperative care of patients undergoing ACLR with QT autografts.

## SURGICAL PROCEDURE

The surgical procedure can involve an all-soft tissue autograft or a bone plug of the superior patella. The all–soft tissue QT autograft for ACLR as described by Slone et al[12] will be discussed in this technical note. The harvest technique allows for a single-bundle graft of sufficient length and large diameter. A small (1.5- to 2-cm) horizontal incision of the QT is made from distal to proximal, just lateral to the superior midpoint of the patella.

The typical QT graft is between 6 and 7 cm in length and 9 and 10 mm in diameter.[14] Its cross-sectional area can be easily predicted with preoperative magnetic resonance imaging by measuring a 1-cm-wide section located 3 cm above the joint line perpendicular to the tendon.[9] The QT autograft is particularly advantageous in young, skeletally immature individuals with a small body habitus, especially when adequate QHS autograft size is less predictable and open physes preclude the use of the patellar tendon. The QT autograft is also a good option for revision ACLR when the BPTB or hamstrings tendons have already been used.[15]

## ADVANTAGES OF THE QT AUTOGRAFT

### Anatomy

The QT offers a unique soft tissue option, with a larger and stronger anatomical area from which to harvest the autograft. Early studies[16,17] revealed that the QT tissue was thicker and longer and had higher collagen levels, contributing to greater strength compared with patellar tendon tissue. Magnetic resonance imaging[14] revealed that the mean thickness of the QT versus BPTB autograft was 6.8 versus 3.7 mm, and mean volume was 11.0 versus 4.0 $cm^3$. The larger QT size does not necessitate larger tunnel sizes in the femur and tibia compared with the BPTB autograft because bone blocks for BPTB autografts are larger than the size of the harvested tendon.

The length and thickness of the QT autograft can be tailored to the patient. This is especially important as smaller autograft sizes ($<$8 mm in diameter) are associated with increased failure rates.[18,19] In a review of 54 patients, Ashford et al[9] demonstrated that 17% had insufficient QHS autograft size for ACLR, whereas none of the patients had insufficient QT size. The smallest diameter for the QT autograft in this study was 8.7 mm. In young patients (ages 4–16 years), QT autograft size measured via ultrasound was sufficient for pediatric ACLR and could be predicted using the patient's age, height, and weight.[20]

Lastly, the minimally invasive harvesting procedure provides a cosmetic benefit over the BPTB autograft, as the incision site is very small and reduces the risk of numbness due to injury of the infrapatellar branch of the saphenous nerve.

### Biomechanics

Evaluation of the extensor mechanism in cadaveric samples showed that the harvested QT could withstand greater tensile loads than the entire intact patellar tendon.[21] The greater collagen density in the QT (20% more than in the patellar tendon) may explain this higher ultimate tensile strength.[16,17] The ultimate load that the QT can withstand is similar to that of the native ACL (2186 and 2160 N, respectively) and significantly higher than that of the BPTB autograft (1581 N).[22] This anatomical and biomechanical evidence may ultimately support enhanced early and long-term clinical and functional outcomes because of less stress on the QT autograft and donor sites. It should be noted, though, that patients with QT autografts may be at increased risk of arthrofibrosis[23] compared with BPTB autografts.[4] Attaining full knee extension early postsurgery is crucial in lessening this risk. (See "Rehabilitation Implications.")

### Clinical Outcomes

The QT autograft displayed viability in multiple recently published systematic reviews[24–27] when compared with BPTB or hamstrings tendon autografts. Importantly, knee stability and graft failure rates were comparable among groups.

In comparison with the BPTB autograft, studies[27–30] of QT autografts have revealed decreased anterior knee pain and donor-site morbidity. We theorize that decreased pain and donor-site morbidity may translate to improved clinical outcomes, especially early postsurgery. For patient-reported outcomes, no differences have been reported for Lysholm,[31] International Knee Documentation Committee,[28–30] or Knee Injury and Osteoarthritis Outcome scores.[30] Additionally, no differences between QT and BPTB autograft groups for isokinetic knee-extensor strength were noted at mean follow-ups of 6 months,[32] 8 months,[33] or 3 years post-ACLR.[28]

Compared with the hamstrings autograft, patients with QT autografts demonstrated better Knee Injury and Osteoarthritis Outcome scores, whereas isokinetic strength values were similar.[34] At 2-year follow-up, the Tegner and Lysholm scores of patients with QT or hamstrings tendon did not differ.[35] Lee et al[36] also found no differences in knee-extensor strength between groups but did find greater knee-flexor strength in the QT autograft group. Preservation of knee-flexor strength may be a protective factor in providing knee stability and preventing rerupture.

Harvesting the QT was previously thought to negatively affect the extensor mechanism, yet this does not appear to be the case. A recent thorough investigation[33] of quadriceps integrity post-ACLR indicated similar limb symmetry indices for all neuromuscular outcomes (quadriceps strength, cross-sectional area, and central activation) of the QT compared with the BPTB autograft. Additionally, the groups did not differ in functional or patient-reported outcomes.[33] Primary analysis of the senior author's institution's clinical cohort of all–soft-tissue QT autografts between 2012 and 2018 (n = 1000, age = 20 $\pm$ 6 years, 43% female) revealed good outcomes (J.W.X., unpublished data, 2019). Knee laxity was within the normal range ($\pm$3 mm) for 97% of patients at 6 weeks and 3 and 6 months. At 6 months, the mean International Knee Documentation Committee score was 85 $\pm$ 14, and limb symmetry indices were 75% and 80% for isokinetic knee extension at 60°/s and 180°/s, respectively. Follow-up in 660 of 1000 patients revealed a graft failure rate of only 4.8%. This early evidence suggests that the QT autograft is a viable option for use in ACLR, especially when considering the following implications for rehabilitation.

## REHABILITATION IMPLICATIONS

The current recommendation is to base rehabilitation on the surgeon's graft choice,[1] yet even the clinical practice guidelines from the American Academy of Orthopedic Surgeons excluded all studies that involved QT autografts.[13] Clinicians will treat more and more patients with QT autografts and thus must be familiar with the rehabilitation implications. Because the QT autograft has demonstrated similar clinical outcomes as other autograft types, it is plausible to maintain standard rehabilitation practices. However, as does any graft type, the QT autograft has unique characteristics that must be considered in the early postoperative period.

**Table. Early Rehabilitation Considerations for Patients Post–Anterior Cruciate Ligament Reconstruction With Quadriceps Tendon Autografts**

| | Considerations |
|---|---|
| Phase I (0–6 wk) | |
| Pain and complications | Monitor for hematomas (pain and focal swelling 2–3 cm around the harvest site) |
| Weight bearing | With crutches for 2 wk (if no meniscal involvement) |
| | >2 wk: Gait retraining with focus on full knee extension |
| Range of motion | Extension goal: equal to nonsurgical limb by 4 wk |
| | Full *passive* extension early is key |
| | Heel props and prone hangs |
| | Focus on terminal knee *active* extension |
| | Straight-leg raises, quadriceps sets, and short-arc quadriceps exercises |
| | Flexion goal: 100° |
| | Begin stretching the rectus femoris at the hip and knee joints |
| | Inferior patellar mobilizations |
| Activation of quadriceps | Neuromuscular electrical stimulation |
| | Closed kinetic chain exercises (squats, lunges, etc) |
| | <4 wk: Body-weight squats |
| | >4 wk: Add weight to squats, body-weight lunges |
| | Open kinetic chain exercises |
| | <4 wk: Straight-leg raises, quad sets, and short-arc quadriceps exercises |
| | Add weight, if no extension lag |
| | >4 wk: Knee extensions through full range of motion (0°–90°) on isotonic weight machine |
| | 2-s hold at end range |
| Testing (6 wk) | Joint laxity, range of motion, thigh-girth measurements |
| Phase II (6–12 wk) | |
| Range of motion | Flexion goal: full flexion |
| | Incorporate quadriceps stretches and inferior patellar mobilizations to increase knee flexion |
| Strength and activation | Continue phase I open kinetic chain exercises |
| | Increase weight according to patient's ability and progression |
| | Increase weight in closed kinetic chain exercises |
| Testing (12 wk) | Joint laxity, range of motion, thigh-girth measurements |
| | Strength testing (isokinetic at 60°/s and 180°/s) |
| Phases III–V (>12 wk) | Follow standardized, criterion-based strengthening; sport-specific training and return-to-activity training and testing, consistent with other graft types |

## Early Rehabilitation

Because the aforementioned biomechanical and anatomical studies have revealed that the QT autograft is stronger[16,21] with a greater cross-sectional area,[14,22] it is possible that the quadriceps can be treated more aggressively without fear of compromising the healing autograft. Achieving full knee extension early postsurgery is of the utmost importance given the large volume and stiffness of the QT autograft. This can be accomplished with exercises that isolate the quadriceps in the end range of knee extension (Table). The additional preservation of knee-flexor strength after ACLR with QT autograft[37] may allow for greater knee-joint stability while aggressively strengthening the quadriceps muscles earlier postsurgery. Aggressive strengthening combines open and closed kinetic chain exercises (Table). Clinicians should not fear the inclusion of early open kinetic chain exercises,[38,39] as they are crucial for isolating the quadriceps femoris to promote gains in strength and activation. Our team has been studying the effects of a protocol that incorporates early open kinetic chain exercises through the full range of knee extension <6 weeks post–QT autograft ACLR and found no differences in anterior knee laxity or strength compared with standard rehabilitation (delay open kinetic chain >6 weeks; J.W.X., unpublished data, 2019). Future researchers should focus on improving rehabilitation for individuals with QT autografts in order to optimize neuromuscular outcomes and functional performance. Early postoperative considerations specific to patients with QT autografts are presented in the Table.

## Complications

As with any graft type, complications do occur. Most complications of the QT autograft occurred when the superior pole of the patella was harvested as a bone plug,[26] with fracture rates of 8.8% at 2-year follow-up.[40] Common complications of the all–soft tissue harvest include hematomas and loss of extension. First, hematomas can present in the initial days after surgery as pain and focal swelling 2 to 3 cm around the harvest site. It is important to differentiate a hematoma from joint effusion and refer the patient to the orthopaedic surgeon if it persists >5 days. Effusion can occur, but a partial-thickness QT autograft harvest does not violate the suprapatellar pouch. It should be noted, though, that a recent systematic review[41] showed no difference in outcomes or complication rates for partial- versus full-thickness QT autografts. Second, loss of extension may be more common because the QT autograft has a greater volume and is stiffer than other autograft types. Given these factors, gaining extension early postsurgery is crucial to facilitate rehabilitation and prevent the need for subsequent surgery (ie, lysis of adhesions). If extension is not addressed, the general quadriceps strength progression will be slow and the patient may never regain full strength. Lysis of adhesions is usually indicated if full extension is not achieved by 8 weeks.[23] In our experience, early lysis of adhesions has been immediately beneficial to the patient.

## CONCLUSIONS

Because its clinical outcomes are similar to those of other autograft types, the QT provides a viable autograft option for use in ACLR. Benefits include stronger, stiffer tissue and preservation of knee-flexor strength, which may allow for more aggressive strengthening earlier postsurgery. However, the greater size and stiffness of the QT autograft require that knee extension be achieved as early as possible to prevent complications such as arthrofibrosis.

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